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(54) **Crimp sleeve, especially for optical fibre cables**

(57) A composite crimp sleeve has an outer sleeve 41 (e.g. of copper) which is deformable, and an inner sleeve 38 which can undergo a predetermined radially inward deformation. The inner sleeve 38 may be intrinsically incompressible (e.g. a stainless steel tube) but have a plurality of longitudinal slots 52 whose closure on compression provides a predetermined reduction in the circumference of base of sleeve 38. The bore remain substantially round, even though conventional crimping will give the outer sleeve 41 a hexagonal surface.

The number and dimensions of the slots may be tailored to apply a desired compression to the outer jacket 12 of an optical fibre 10 without damaging the mono-fibre 16. An uncompressed portion 56 serves as an anchor.

An S.M.A. plug may use a crimp sleeve 41, 38 for securing an optical cable and a clamp for accurate positioning of the fibre end face. The sleeves 41, 38 may be combined with other plug components to provide a compact plug with very little of the unsheathed fibre left unclamped.

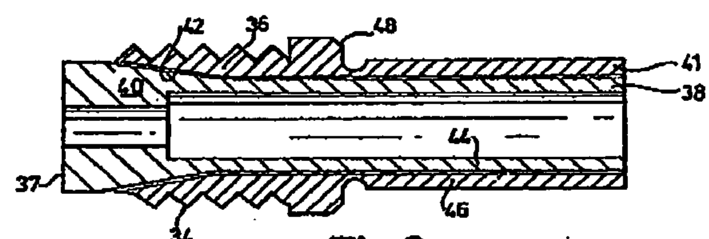

Fig.2.

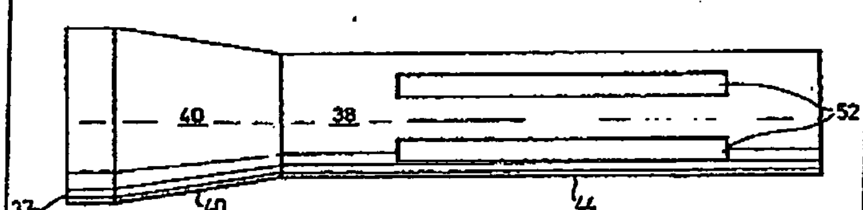

Fig.3.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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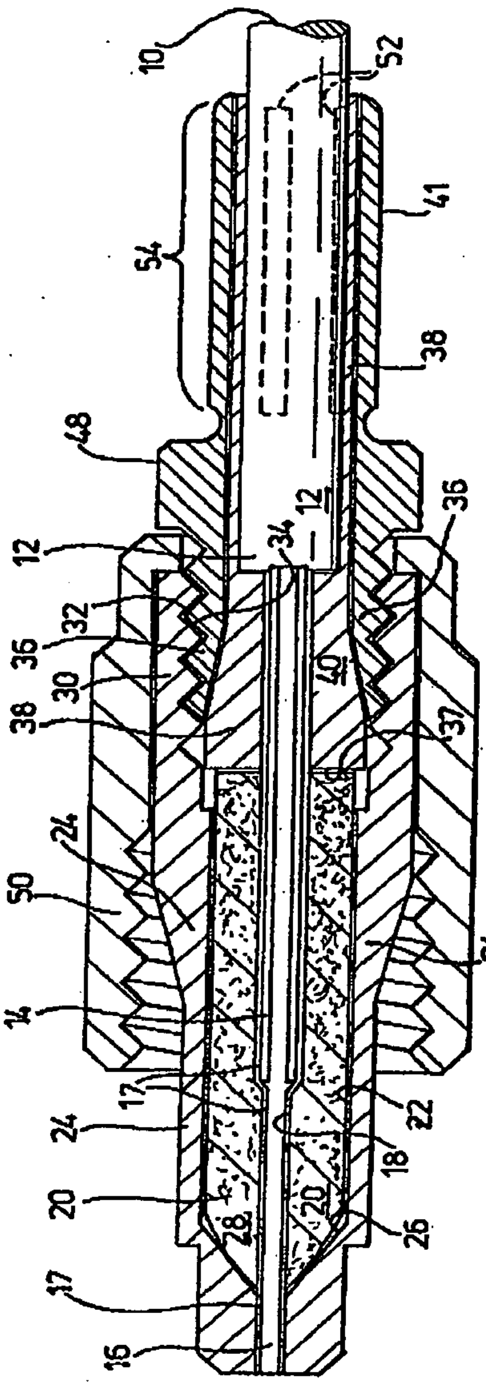

Fig.1.

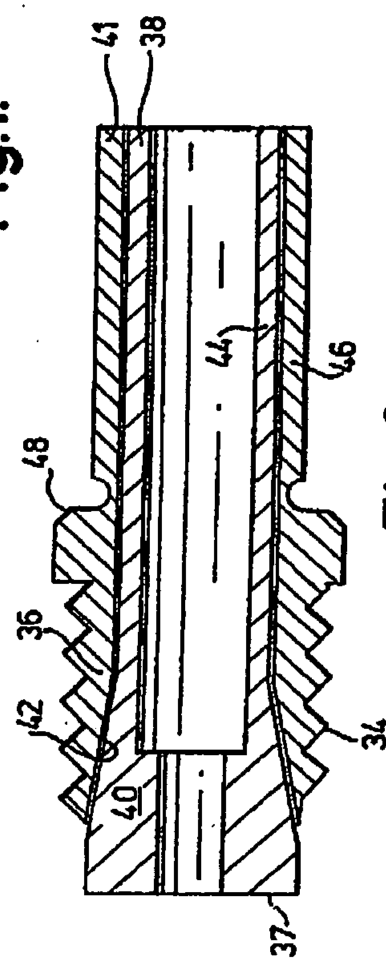

Fig.2.

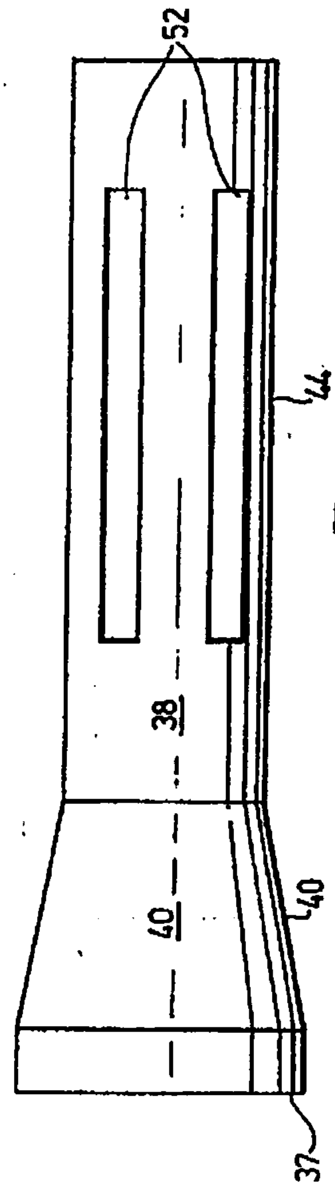

Fig.3.

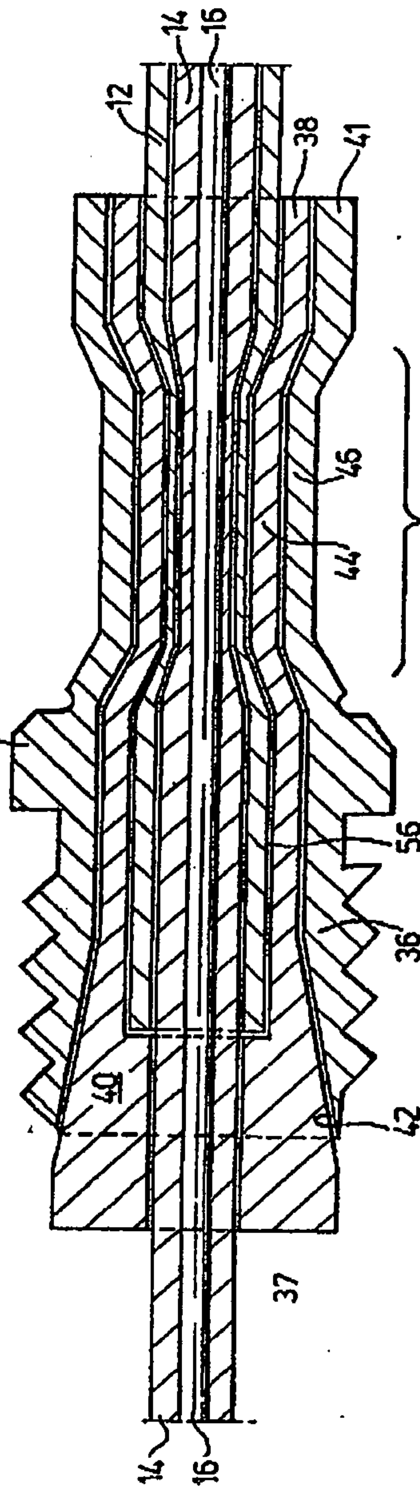

Fig.4.

SPECIFICATION

Crimp sleeve, especially for optical fibre cables

The present invention relates to the securing together of a sleeve and an inner member by crimping, and in particular to a method and means which may be usable in cases where the inner member would be damaged by the forces exerted on it in a conventional crimping process. In a preferred form it concerns the securing of elements to optical fibres, especially mono-fibres.

Crimping is widely used in the electrical industry for securing terminal elements on the end positions of electric conductors. The conventional process involves mounting a metal sleeve coaxially about the conductor and compressing it radially (with a crimping tool), so that it compresses and deforms the conductor, causing cold welding thereof. If the conductor in a coaxial cable having a central conductor, a dielectric sheath, and an outer conductive flexible tube or braid, then the crimping process causes cold-welding of the flexible tube or braid, which is then held rigid. However, the central conductor and its dielectric are not fixed in place by the crimping process; only the rigidity conferred by the terminal element (e.g. a pin or socket) may serve to fix them axially.

A mono-optical fibre with one or more sheaths has a form rather resembling a coaxial cable. However, the central fibre is finer and much more prone to damage than the electrical conductor in an ordinary coaxial cable. This means that an attempt to provide it with a conventional crimped sleeve would distort and/or damage the fibre to an unacceptable degree. Furthermore the fibre is generally too delicate for fixture to a terminal element to provide axial location. Probably for these reasons, there seem to have been no previous attempts to apply crimping to mono-optical fibres.

According to a first aspect of the present invention there is provided a crimp sleeve for crimping around a generally cylindrical elongate element, said sleeve comprising an outer tube, at least a longitudinal portion of which is radially inwardly deformable to take a permanent set, and an inner sleeve member which is located radially within the outer tube and at least a longitudinal portion of which is radially inwardly deformable to a predetermined extent, said predetermined deformation being effectable by deformation of the outer tube.

In further aspects the invention provides: a method of applying a crimp sleeve; an S.M.A. pattern plug incorporating a crimp sleeve; and a fibre optic cable with a crimp sleeve and/or S.M.A. pattern plug mounted thereon.

A preferred embodiment of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is an axial section through an S.M.A. pattern plug for a sheathed mono-optical fibre (shown unsectioned), including an uncrimped crimp sleeve embodying the invention;

Figure 2 is a view similar to Fig. 1 but showing only the inner and outer tubular sleeve elements which make up the crimp sleeve;

Figure 3 is a side elevation of the inner tubular sleeve element; and

Figure 4 is a sectional view similar to Fig. 2 showing the sleeve elements after crimping with a sheathed mono-optical fibre in place.

Referring first to Fig. 1, an end portion of an optical fibre cable 10 is located within an S.M.A. pattern plug which incorporates: (a) a fibre clamp; (b) a thread-expanding lock nut; and (c) a crimp sleeve embodying the present invention.

The optical fibre cable 10 has an outer jacket 12 over a strengthening layer. These have been removed from part of the cable 10 within the plug, to expose an inner jacket 14. This has been removed from the very end portion, exposing the fibre clad only in a buffer layer 16. A special fibre sleeve 17, marketed by Raychem as the "Raychem Fiber Sleeve", has been applied over the part of the cable from which the outer jacket 12 has been removed. This is fast with the fibre on the outer portion thereof, and serves to increase its effective diameter. This facilitates the manipulation and mounting of the fibre, e.g. by avoiding the need to drill bores of very small diameter (*ca* 200 μm) to house it.

A portion of the fibre, part of which retains its inner jacket 14 (with the sleeve 17 outside it) is within a bore 18 of a fibre clamp 20. This is located in a cavity 22 in the front section 24 of the plug body. The front end surface 26 of cavity 22 (at the left in Fig. 1) is frusto-conical. The front end 28 of the clamp 20 is rounded, and has axial slots (not shown) extending to the bore 18 which in this region is of a diameter to receive only the fibre *without* the inner jacket 14 (but with the sleeve 17). The front section 24 of the plug body has a rear portion 30 with an internal thread 32 which engages an external thread 34 on a plug body nut 36 (which is integral with an outer crimp sleeve 41). Screwing the plug body front section 24 and the plug body nut 36 together compresses the clamp 20 between the front face 37 of an inner crimp sleeve 38 and the frusto-conical surface 26 of cavity 22. This causes inward compression of the front end 28 of the clamp 20 (which is squeezed by the frusto-conical surface 26). This causes narrowing of the axial slots in the clamp 20, and hence of the bore 18 within the front end 28 of the clamp, which thus grips the fibre 10 firmly (through the sleeve 17 and buffer layer 16). This form of clamp is described in greater detail in British Patent Application 79.17999. It provides for very accurate location (e.g. ±25 μm) of the end surface of the fibre.

Referring more specifically to Fig. 2, the outer (to the left in the figs) end portion of the inner crimp sleeve 38 has a frusto-conical portion 40, which narrows to the right. The plug body nut 36 (integral with the outer crimp sleeve 41, which is coaxial with inner sleeve 38) has a cooperating internal frusto-conical surface 42. Movement of the plug body nut 36 to the left relative to the

inner crimp sleeve 38 (by screwing) causes the outer (leftward) portion of the nut 36 to be urged generally radially outwardly by the cooperation of the frusto-conical surfaces. Some radial expansion is possible owing to axial slots (not shown) in the outer portion of the nut 36. Thus the thread 34 of nut 36 is forced tightly against the internal thread 32 of the plug body front section 24, securing the screw-connection against working loose. This type of expanding screw-thread coupling is described in more detail in British Patent Application 79.31790.

The inner (38) and outer (41) crimp sleeves each include an element (40, 36) forming part of the main plug assembly (seen in Fig. 1) and a cylindrical tubular portion (44, 46) respectively. The outer sleeve 41 also has an annular rib 48 for location of a plug retaining nut 50 (Fig. 1). The sleeves 38, 41 are dimensioned so that there is a close fit between them. Referring to Fig. 3, the inner sleeve 38 has a plurality of longitudinal slots 52 machined into its cylindrical portion 44. The outer sleeve 41 is formed of a readily deformable material, e.g. copper. The inner sleeve 38 is formed of a material, e.g. stainless steel, such that a tube of the dimensions employed is substantially incompressible by the pressure exerted by a conventional crimping press. However, pressure applied to the tubular portion 44 can cause deformation by closing the slots. Once the opposed longitudinal edges of each slot have been forced together (except for their end portions), the sleeve 38 is essentially incompressible. The amount of radial contraction which the sleeve 38 can thus undergo is determined by the number and dimensions of the slots 52. Thus the sleeve 38 can be 'tailored' to assume a desired final configuration.

When an assembly as seen in Fig. 1 is subjected to crimping over the region 54, the sleeves 38, 41 are deformed until the inner sleeve 38 reaches its final configuration. With a conventional crimping tool, the compressed region of the outer sleeve 41 will be given an exterior with a hexagonal cross-section. However, the controlled deformation of the interior sleeve 38 will leave it with substantially circular inner and outer surfaces. Thus a fibre cable 10 within the compressed portion of the sleeve is subjected to substantially uniform pressure. As seen in Fig. 4, the deformability of the sleeves 38, 41 is tailored so that the crimping compresses the inner and outer jackets 14, 12 of the cable 10, without harming the fibre 16. Fig. 4 also shows that the outer jacket 12 has been left on the cable 10 for some length 56 forward of the crimping region 54. After crimping, the uncompressed length 56 cannot pass through the crimped neck, and thus forms an anchor to prevent the mono-fibre from being pulled out of the plug assembly. Thus the crimping produces a firm and secure connection of considerable strength between the cable and the plug, while the clamp 20 provides for very accurate positioning of the fibre itself.

The dimensions of the crimp sleeves 38, 41 and the number and dimensions of the slots 52 will be determined by the properties of the fibre cable 10 with which they are to be used. By way of example, with a cable having a fibre of diameter 200 μm, an inner jacket of diameter 610 μm, and an outer jacket of diameter 2.00 mm, there were used an inner crimp sleeve having internal and external diameters of 2.10 and 2.80 mm, and an outer crimp sleeve having inner and outer diameters of 2.85 and 3.00 mm (all of these dimensions refer to the uncrimped condition). The inner crimp sleeve had four symmetrically disposed slots 7.00 mm long and 0.40 mm wide. After crimping each slot was closed for about 5 mm of its length, with a distorted 1 mm portion at either end. The crimping reduced the inner circumference of the inner crimp sleeve by substantially the total width of the slots, $4 \times 0.40 = 1.60$ mm (in fact the measured value was 1.40 mm).

In the illustrated plug assembly, the crimp sleeve elements (38, 41) are integral with other elements (40, 36, 48). This is advantageous as it gives a more compact assembly. It would also be possible to combine the fibre clamp 20 with the inner crimp sleeve 38 as a unitary component. This would enable the fibre sleeve 17 and the plug retaining nut 50 to be reduced in length, giving a still compacter assembly and a reduction in the length of fibre which is unclamped.

CLAIMS

1. A crimp sleeve for crimping around a generally cylindrical elongate element, said sleeve comprising an outer tube, at least a longitudinal portion of which is radially inwardly deformable to take a permanent set, and an inner sleeve member which is located radially within the outer tube and at least a longitudinal portion of which is radially inwardly deformable to a predetermined extent, said predetermined deformation being effectable by deformation of the outer tube.

2. A crimp sleeve according to claim 1, wherein the predetermined deformation of said position of the inner sleeve member causes it to define a generally cylindrical internal space of predetermined diameter.

3. A crimp sleeve according to claim 1 or 2, wherein the inner sleeve member comprises a tube having in its undeformed state a plurality of longitudinal slots, radially inward deformation of the member causing the slots to narrow until at said predetermined extent of deformation they are substantially closed.

4. A crimp sleeve according to any one of the preceding claims wherein said outer tube is of copper and said inner sleeve member is of stainless steel.

5. A crimp sleeve according to any one of the preceding claims suitable for crimping around an optical fibre cable.

6. An S.M.A. pattern plug or other terminal element for a mono-optical fibre including a crimp sleeve according to claim 5 for securing a fibre cable containing the mono-fibre.

7. An S.M.A. pattern plug according to claim 6, wherein said outer tube and inner sleeve members are integral with further elements of the plug.

8. A plug according to claim 7, wherein the outer tube and inner tube are respectively fast with an externally threaded plug body nut for screw attachment to a front section of the plug body and a thread-expanding taper which cooperates therewith to lock said screw-attachment substantially as described in British patent application 79.31790.

9. A terminal element according to any one of claims 6 to 8 crimped to an end portion of an optical fibre cable, the deformation of the sleeve portion having reduced the circumference of an outer sheath of the cable and there being forward of the deformed sleeve portion a portion of said outer sheath of substantially unreduced circumference which serves to anchor the fibre in the crimp sleeve against rearward axial pulling.

10. A method of applying a crimp sleeve to a generally cylindrical elongate element comprising the steps of mounting an outer tube and an inner sleeve member, both according to any one of claims 1 to 5, about the elongate element, and compressing the outer tube with a crimping press until the inner sleeve member has undergone its predetermined deformation.

11. A method according to claim 10 of applying a crimp sleeve to an optical fibre cable.

12. A crimp sleeve or S.M.A. pattern plug assembly substantially as described herein with reference to and as illustrated in the accompanying drawings.

13. A method of applying a crimp sleeve substantially as described herein with reference to the accompanying drawings.

14. An optical fibre cable when treated according to the method of claim 11 or claim 13.

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